JPL

ADVANTAGES OF REGENERATIVE RANGING FOR DEEP SPACE NAVIGATION

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DESCANSO Symposium

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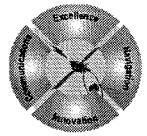
ADVANTAGES OF REGENERATIVE RANGING

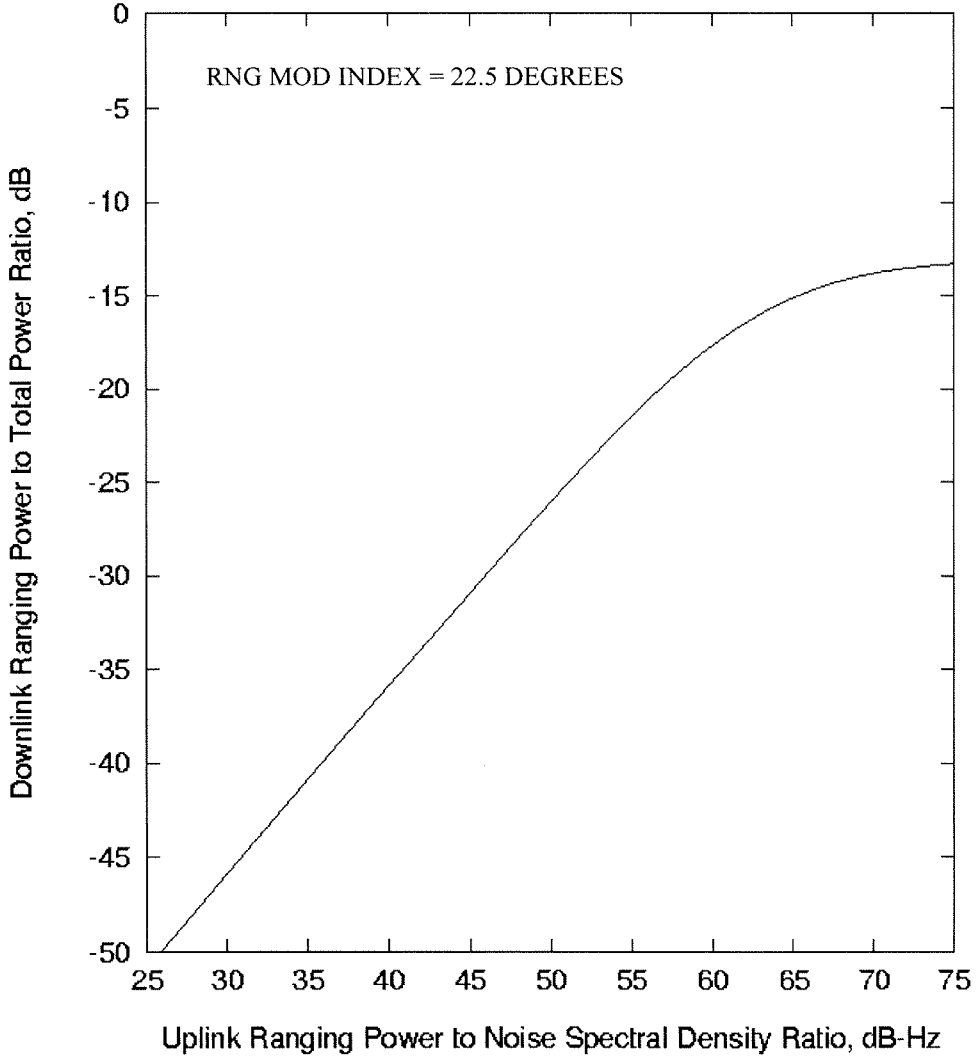


CURRENT RANGING DESIGN

- RANGING SIGNAL IS MODULATED ONTO THE UPLINK
- SPACECRAFT DEMODULATES THE RANGING SIGNAL AND FILTERS IT WITH A 1.5 MHz FILTER
  - 1.5 MHz OF NOISE IS INCLUDED WITH THE SIGNAL
- DOWNLINK CARRIER IS MODULATED BY THE FILTERED RANGING SIGNAL
  - NOISE DEGRADES THE DOWNLINK
- GROUND EQUIPMENT DEMODULATES THE RANGING SIGNAL FROM THE CARRIER AND CORRELATES IT WITH THE REFERENCE
  - INTEGRATION TIME IS INCREASED TO REDUCE THE NOISE

ADVANTAGES OF REGENERATIVE RANGING

TURN AROUND DEGRADATION



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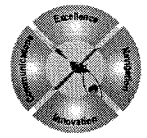

SEQUENTIAL RANGING

- SERIES OF SQUARE WAVE TONES SENT
  - FREQUENCY OF EACH TONE HALF THE FREQUENCY OF THE PREVIOUS ONE
  - HIGHEST FREQUENCY TONE CALLED THE CLOCK COMPONENT
  - TOTAL NUMBER OF COMPONENTS (N) DEPENDS ON THE AMBIGUITY TO BE RESOLVED
- CLOCK SENT FOR PERIOD OF TIME (T1 SECONDS)
  - THEN EACH COMPONENT SENT FOR T2 SECONDS
- CLOCK SENT AGAIN FOR DRVID (DIFFERENCED RANGE VS INTEGRATED DOPPLER) MEASUREMENTS
  - T3 SECONDS FOR EACH DRVID MEASUREMENT
  - NDRVID MEASUREMENTS
- TOTAL TIME FOR 1 RANGE MEASUREMENT (CYCLE TIME) IS
  - (2+T1) + (1+T2)*(N-1) + NDRVID*(2+T3) + 1
- SINCE EACH COMPONENT MUST BE CORRELATED AND INTEGRATED SEPARATELY, ALL ACQUISITIONS MUST START AT BEGINNING OF SEQUENCE

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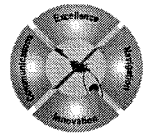

REGENERATIVE RANGING

- INSTEAD OF FILTERING THE RECEIVED SIGNAL PLUS NOISE, THE RANGING SIGNAL IS TRACKED ON THE SPACECRAFT
- ONCE THE SPACECRAFT LOCKS TO THE RANGING SIGNAL, THE REGENERATED SIGNAL IS USED TO MODULATE THE DOWNLINK CARRIER
  - THIS ALLOWS SIGNIFICANT REDUCTION IN THE NOISE ON THE SIGNAL, FROM 1.5 MHz TO THE SIGNAL TRACKING LOOP BANDWIDTH
- THIS REQUIRES THAT THE SPACECRAFT HAVE SOME KNOWLEDGE OF WHAT THE RANGING SIGNAL LOOKS LIKE AND THAT THERE IS ENOUGH SNR TO LOCK
  - SEQUENTIAL SIGNAL IS NOT A GOOD CANDIDATE, DUE TO LONG CYCLE TIMES AND VARIABLE PARAMETERS

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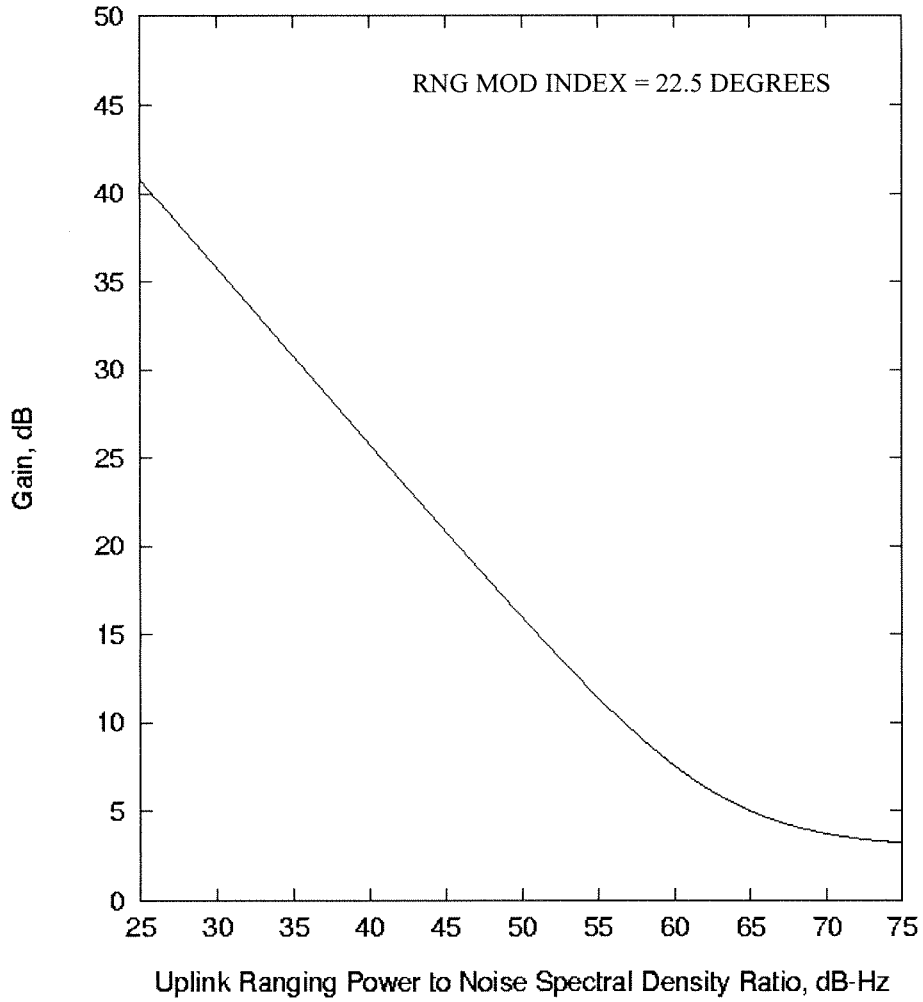
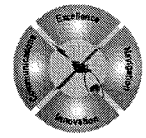
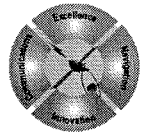
REGENERATIVE RANGING GAIN





PN CODE DESCRIPTION

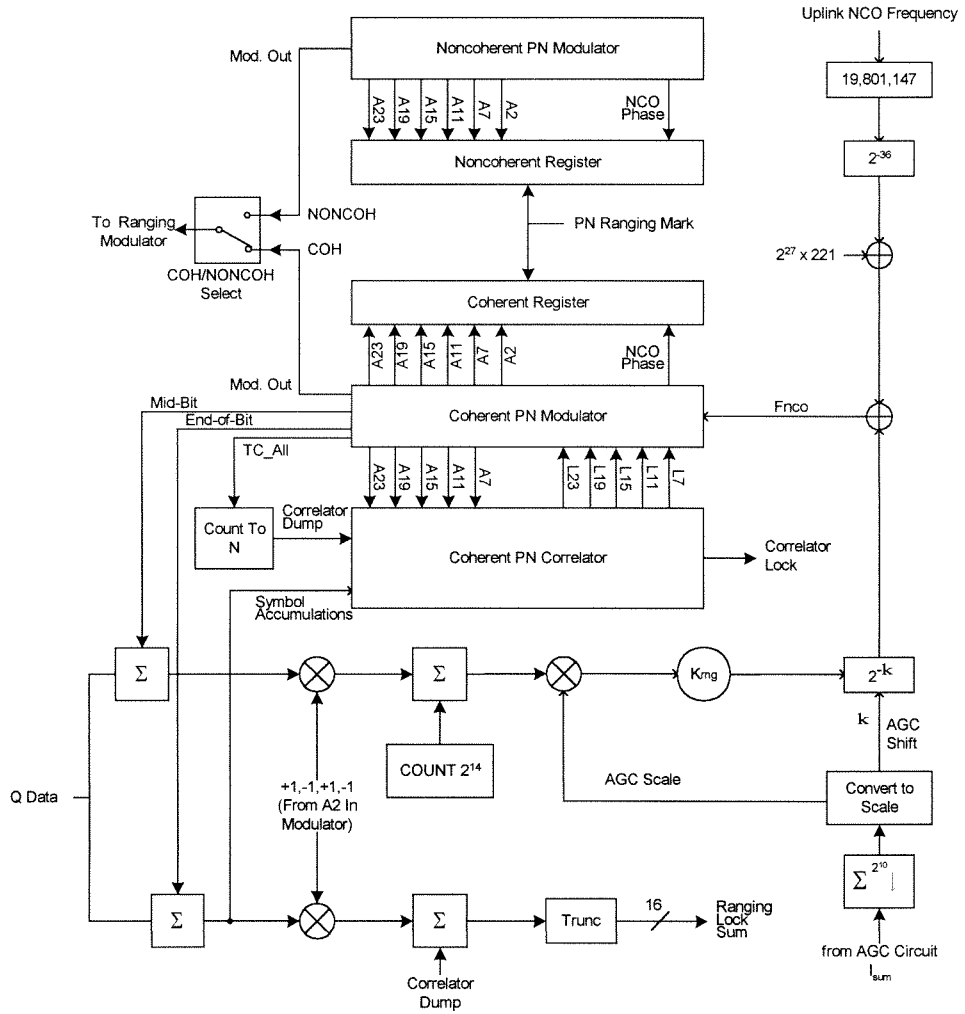
- PSEUDO-NOISE (PN) RANGING PROVIDES AN EASIER SIGNAL TO LOCK TO
- PN SIGNAL IS GENERATED BY OR'ING THE CLOCK COMPONENT WITH THE RESULT OF AND'ING 5 PN SEQUENCES
  - SEQUENCES OF LENGTH 7, 11, 15, 19, 23
  - RESULTING SEQUENCE IS 1,009,470 CHIPS LONG
  - CLOCK RATE IS APPROXIMATELY 1 MHz
    - RESULTING CYCLE TIME IS 0.5 SECONDS (2 CHIPS PER CLOCK CYCLE)
    - CLOCK IS FREQUENCY COHERENT WITH THE UPLINK CARRIER
- PN SIGNAL LOOKS LIKE A SQUARE WAVE AT 1 MHz, WITH A FEW ERRORS



STM DESIGN

- THE SPACECRAFT TRANSPONDING MODEM (STM) HAS IMPLEMENTED THE REGENERATIVE CIRCUITRY
- THE CARRIER FREQUENCY IS SCALED TO GET THE CLOCK FREQUENCY
  - SINCE ONLY PHASE NEEDS TO BE TRACKED, A FIRST ORDER PHASE LOCKED LOOP IS USED TO TRACK THE CLOCK (CHIP) PHASE
- ONCE THE CHIPS ARE IN LOCK, THE SIGNAL IS CORRELATED AGAINST THE PN SEQUENCE
  - CORRELATIONS ARE DONE AGAINST THE SUBSEQUENCES, SO ONLY 75 CORRELATIONS ARE NEEDED
  - FOR WORST CASE SIGNAL STRENGTH, ONLY 18 SECONDS INTEGRATION TIME NEEDED
- WHEN OFFSET IS DETERMINED, PN SEQUENCE USED TO MODULATE DOWNLINK CARRIER

REGENERATIVE CIRCUIT



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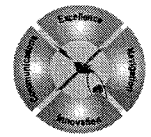

USES OF IMPROVEMENT

- THE GAIN IN RECEIVED RANGING POWER CAN BE USED IN SEVERAL WAYS:
  - REDUCE THE INTEGRATION TIME ON THE GROUND (TO REDUCE THE TRACKING TIME DEVOTED TO RANGING), GIVING THE SAME MEASUREMENT VARIANCE
  - KEEP THE INTEGRATION TIME ON THE GROUND THE SAME, REDUCING THE VARIANCE ON THE MEASUREMENT
  - REDUCE THE DOWNLINK RANGING MODULATION INDEX, KEEPING THE INTEGRATION TIME ON THE GROUND THE SAME, PROVIDING MORE POWER FOR TELEMETRY

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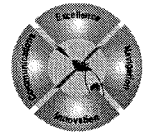

MARS GLOBAL SURVEYOR (MGS) EXAMPLE

CURRENT

NUMBER OF COMPONENTS	18
NUMBER OF DRVID	0
T1 (SEC)	20
T2 (SEC)	20
T3 (SEC)	0
CYCLE TIME (SEC)	210
UPLINK Pr/N0 (dB-Hz)	44.9
DOWNLINK Pr/N0 (dB-Hz)	10.0

WITH REGENERATION

SPACECRAFT INTEGRATION TIME (SEC) (ASSUMING 0.999 PROB. OF ACQ.)	0.5
DOWNLINK Pr/N0 GAIN (dB)	20.6

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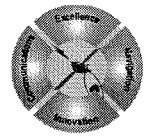

CASSINI EXAMPLE

	VENUS CRUISE	SATURN
CURRENT		
NUMBER OF COMPONENTS	10	TBD
NUMBER OF DRVID	0	TBD
T1 (SEC)	1248	TBD
T2 (SEC)	60	TBD
T3 (SEC)	0	TBD
CYCLE TIME (SEC)	1800	TBD
UPLINK Pr/N0 (dB-Hz)	35.8	61.8
DOWNLINK Pr/N0 (dB-Hz)	-8.4	12.0
WITH REGENERATION		
SPACECRAFT INTEGRATION TIME (SEC) (ASSUMING 0.999 PROB. OF ACQ.)	2.3	0.5
DOWNLINK Pr/N0 GAIN (dB)	27.1	6.3